6.4 Technical Review
March 2014

Project: **Preparing Tactical Ocean Optical Products for Future Polar-Orbiting Sensors: Automated Optical Processing System (AOPS)**

PI: Sherwin Ladner
Email: ladner@nrlssc.navy.mil
Phone: 228-688-5754

Performers: R. Crout, A. Lawson – NRL
P. Martinolich, J. Bowers – QNA
R. Arnone, R. Vandermeulen - USM

Customer POCs – P. Lyon, D. Berkshire - NAVO

Preparing Tactical Ocean Optical Products for Future Polar-Orbiting Sensors: Automated Optical Processing System (AOPS)

Summary of Capabilities, Accomplishments and Plans

Summarize FY13-14 Delivered Capability

- AOPS v4.8 VTR delivered Q1FY13 provided a real time operational capability for tactical surface optical products from NPP VIIRS (no cal/val) and GOCI (beta manual w/o cal/val)
- AOPS v4.10 upgrade planned FY14 delivery allows NPP VIIRS with cal/val and the new operational GOCI with cal/val
- Satellite products include: water clarity, SDV/diver vulnerability/visibility, LIDAR penetration depth, chlorophyll / biological activity, water mass tracking, diffuse light attenuation, total light absorption, backscattering and beam attenuation, circulation model evaluation, inputs for TODS and models
- Current products used by MIW, ASW and NSW Reach Back Cell for mission planning and operations

FY13-14 Accomplishments/Challenges/Issues

- Delivered initial VIIRS and beta GOCI (AOPS v4.8) w/VTR Q1FY13, included upgrades for QAA IOP algorithm and new MODIS calibration
- AOPS v4.10 (validation in final stages, VTR draft) includes:
    - New MODIS cross-calibration and file formats
    - implements and evaluated VIIRS MOBY gains
    - Implements new VIIRS Cloud Mask (VCM)
    - Automates real-time GOCI processing w/new aerosol and Rayleigh tables and navigation improvements.
- Collected rrs and IOP's from NPP VIIRS cal/val cruises in Northern Gulf of Mexico (GEOCAPE/NRL).
- Challenges/Delays due to IOP evaluation: establishing in situ data and processing MODIS, VIIRS and GOCI data

Summarize FY14 Plans

- New AOPS v4.10 with VTR Q2FY14.
- Complete initial GOCI cal/val (vicarious calibration)
- Implement and test GOCI frame correction to remove artifacts due to overlap and solar/sensor angles.
- Continue cal/val for operational sensors (VIIRS,GOCI) including real-time updates for Aeronet-OC sites and vicarious calibration
- Establish data source (NOAA,NASA,ESA) for Sentinel 3A OLCI data including proxy/sample test datasets for initial implementation and preparation for launch.
- Implement band-sharpening technique for enhanced NPP VIIRS ocean color products (375m resolution).
- Complete evaluation and implementation of new LMI IOP algorithm. Benefits spectral band shift to desired wavelength (531nm) for diver visibility calculation for all sensors.
- NRL coastal cruises: RV/Ocean Color for Validation (rrs, IOPs)

Funding

($K)	FY11	FY12	FY13	FY14
AOPS	400	385	357	378
Total	400	385	357	378

Preparing Tactical Ocean Optical Products for Future Polar-Orbiting Sensors: AOPS

FY13-14 Major Objectives & Milestones

MS Event/Action/Improvement Objective	Completion and/or Delivery Quarter/FY	Description of Capability Completed and/or Delivered
AOPS v4.8	**Delivered w/ VTR 1QFY13**	**Provides naval operations a real time operational capability to provide tactical surface optical properties in support of MIW, ASW and SpecWar for operational VIIRS (no cal/val) and GOCI (beta-non-automated, no cal/val).**
AOPS v4.10	**Development Completed and delivery planned for 2QFY14**	**Provides naval operations a real time operational capability to provide tactical surface optical properties in support of MIW, ASW and SpecWar for operational VIIRS (vicarious gains) and GOCI (init operational version, no cal/val).**

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Milestone Chart

Tactical Ocean Optical Products															
•TASKS	FY11				FY12				FY13				FY14			
	Q 1	Q 2	Q3	Q4	Q1	Q 2	Q3	Q4	Q 1	Q2	Q 3	Q4	Q1	Q2	Q3	Q4
1 - Develop real-time ocean products from ocean color sensors and maintain data streams (NPP VIIRS, GOCI, OLCI)			**D**				**D**					**D**				**D**
2 - AOPS Transition and OpTest				**V**	**O**				**V**	**O**			**V**	**O V**	**O**	
3 - Product validation real time val/cal "network" for monitoring global satellite products & uncertainty w/IOP alg. validation				**D**			**D**					**D**	**D**			
4 - Integrate GOCI-1 into Operations and Evaluate JPSS1, DWSS, Sentinel 3 , GOCI - 2 for operational products			**CV_b**					**CG b CV_o**				**CG_o**				

Milestones indicate **V**TR panel-accepted and **O**PTEST

VIIRS Operational Processing in AOPS v4.10 100% complete with cal/val; Initial Draft of VTR Complete;
Transition/VTR Complete (Q2FY14)

GOCI Operational Processing in AOPS v4.10 100% complete w/o cal/val; Initial Draft of VTR Complete;
Transition/VTR Complete (Q2FY14). Initial cal/val in FY14.

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FY13-14 Transition Plan Summary

- **TRANSITION APPROVAL STATUS:**
  1. FY13 TP approved, FY14 TP awaiting signatures from PMW120, CNMOC and OPNAV.

- **INPUTS***:* Inputs include satellite derived top of atmosphere radiance imagery (level 1) from IDPS and outside data streams (via ftp). Existing data source processing capabilities include AQUA-MODIS, NPP-VIIRS, and COMS-GOCI. Additional data source processing capabilities will include, JPSS1-VIIRS, Sentinel 3A-OLCI, and COMS-GOCI-II

- **OUTPUTS / PRODUCTS:** Ocean optical environment including water clarity, diver visibility, SDV/diver vulnerability/visibility, LIDAR penetration depth, chlorophyll/biological activity, water mass tracking, diffuse light attenuation, total light absorption, backscattering and beam attenuation, circulation model evaluation, inputs for TODS 3D (beam attenuation) and other models (short wave heat flux)

- **ACCEPTANCE CRITERIA:** VTR includes validation from regions around the world including matchups with field data (where available) and inter-sensor comparisons. Installation and OpTest of the AOPS on NAVO A2 computer. Validation test panel identified

- ***OPERATIONS AND MAINTENANCE REQUIREMENTS***
  1. 1 month for OPEVAL and training will be required.
  2. 1 FTE will be required to run operationally after transition.

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IMPACT of Possible FY15 Funding Termination

- By the end of FY14, the operational center will have the capability to produce operational support products from the MODIS, VIIRS and GOCI ocean color sensors. However, this capability requires periodic (3-6 month) updates of the sensor gains (vicarious calibration) due to frequent calibration upgrades (sensor and radiometric drift and degradation) for inter-sensor accuracy, stability and consistency.

- MODIS Aqua has surpassed it's end-of-life expectancy and NPP VIIRS is into it's third year. The integration of new polar-orbiting sensors is required to sustain operational support using ocean optical products.

- If FY15 funding is not provided, the following negative impacts will occur:
  - Sensor calibration tables will be frozen to the latest in the format which is readable by existing AOPS software. NASA continually changes the format of these formats. Degradation of satellite borne sensors will show up in products
  - No new satellite sensors (Sentinel 3A OLCI, JPSS VIIRS, COMS 2-GOCI) will be supported.
  - No current/new software, sensor and/or algorithms updates/improvements could be implemented.

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Way Forward

Project Deliverables:

- AOPS VTR and manuals
- AOPS software updates to process NPP, GOCI and Sentinel-3A sensors
- Satellite specific mods to existing operational algorthms for water properties, utilizing the NAVO A2 system
- Assessment of the stability of satellite sensors and derived products using multiple in situ sources (Aeronet-Ocean Color network, cal/val cruise data, other operational sensors, etc. in VTR)
- Define the inter-sensor uncertainty of multiple satellites in different coastal regions for operational continuity in VTR

Follow-on Upgrades:

- The AOPS system will require future upgrades based on the launch of the Sentinel 3A, Sentinel 3B, JPSS 1, and COMS 2 satellites. Continued monitoring and cal/val is required to maintain stable algorithms and products.

Sensor Updates (Operational and Future):

- MODIS Aqua is degrading at a faster rate than in previous years and is nearing it's end-of-life expectancy.
  - NASA calibrations upgrades are slower than the degradation process. NRL may perform vicarious calibration.
  - NASA will be performing another MODIS/MOBY vicarious calibration in 2014
- S-NPP VIIRS calibration updates are more frequent and require continuous monitoring and possibly more vicarious calibrations (NRL vicarious calibration August 2013). Investigating a combined approach of possible green (coastal Aeronet sites) to blue (MOBY) water vicarious calibration.
- NASA currently developing a KIOST mirror site for GOCI (8 hours) for U.S. R&D. NASA used NRL initial implementation in their processing and recently supplied GOCI sensor specific Rayleigh and aerosol tables.
- Collaborating with ESA to obtain Sentinel-3 OLCI data stream (proxy & operational), in additional to

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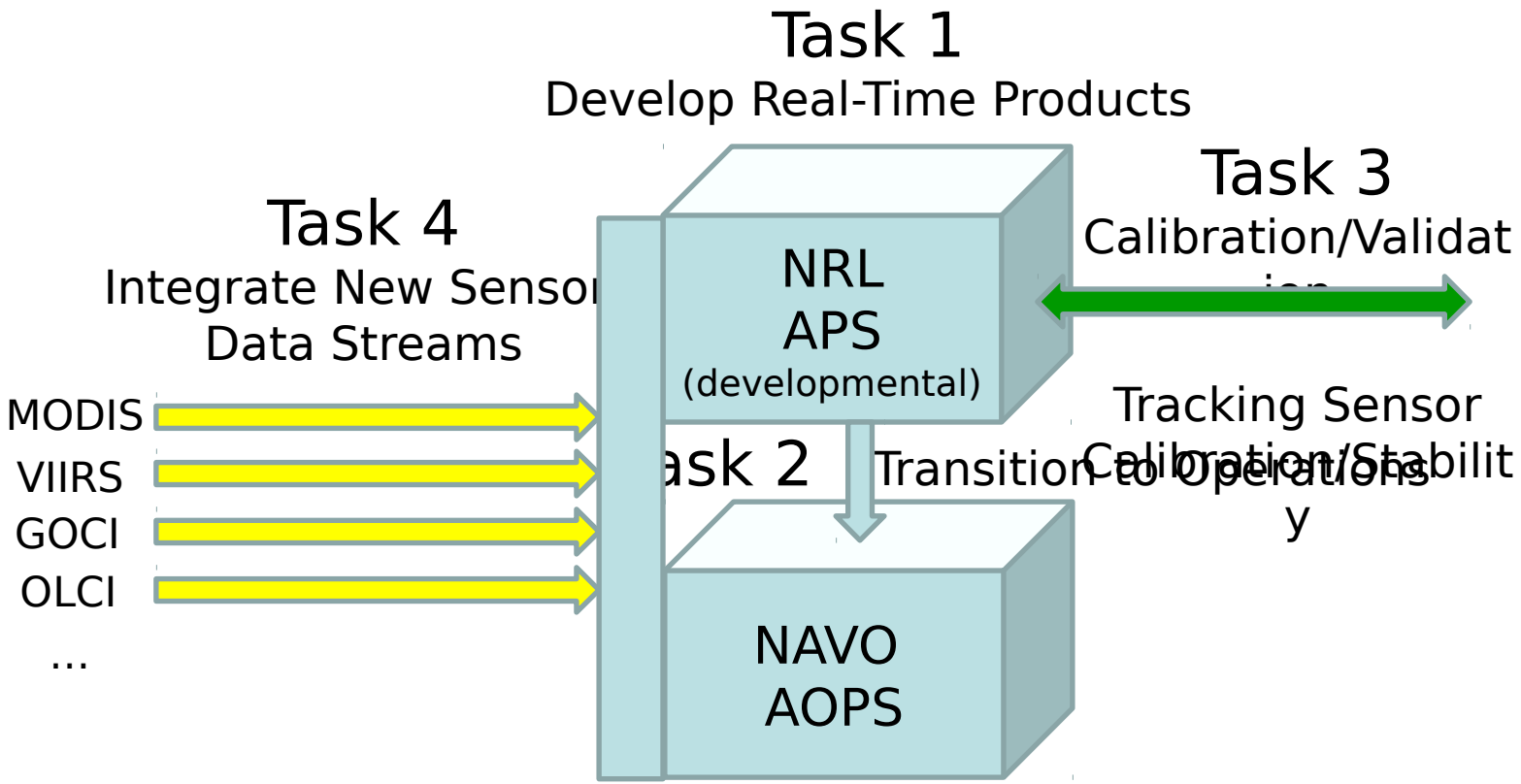
Task Descriptions



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Transition of AOPS for VIIRS and initial GOCI Operations

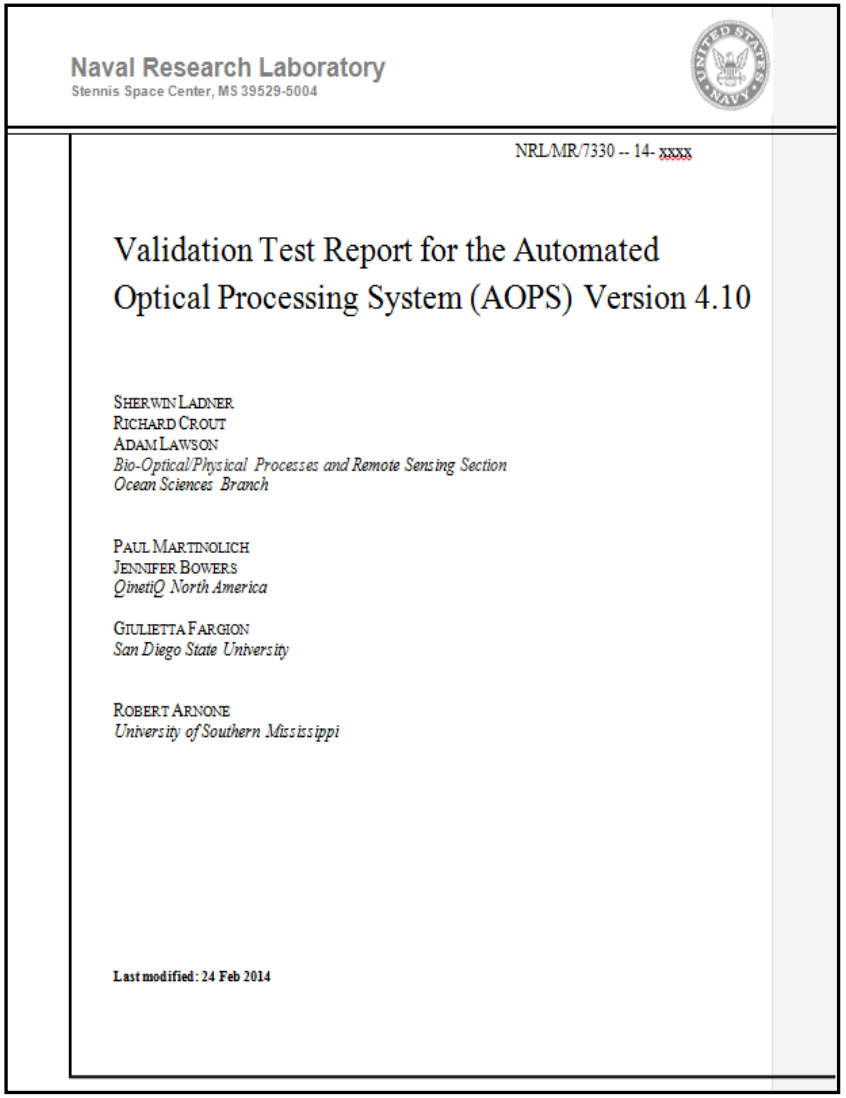
VTR for the initial VIIRS processing AOPS Ver. 4.8 delivered NOV 2012

- OPTEST began DEC 2012, completed FEB 2013

Current VTR for AOPS ver. 4.10 in final draft, ~ 45 pages – VIIRS w/cal/val & GOCI initial version for real-time processing w/o cal/val

<u>Validation utilizes:</u>

- In situ observations from the MOBY buoy, Global Aeronet-OC (AAOT,Ieodo, Gageocho)
- Cross Platform (satellite-to-satellite) matchups in Italy, Korea, Arabian Gulf
- Evaluation of IOP performance in coastal and offshore waters in Northern Gulf of Mexico (GEOCAPE, NRL)
- GOCI comparisons to MODIS, VIIRS



Naval Research Laboratory
Stennis Space Center, MS 39529-5004

NRL/MR/7330 -- 14- xxxx

Validation Test Report for the Automated Optical Processing System (AOPS) Version 4.10

SHERWIN LADNER
RICHARD CROUT
ADAM LAWSON
Bio-Optical/Physical Processes and Remote Sensing Section
Ocean Sciences Branch

PAUL MARTINOLICH
JENNIFER BOWERS
QinetiQ North America

GIULIETTA FARGION
San Diego State University

ROBERT ARNONE
University of Southern Mississippi

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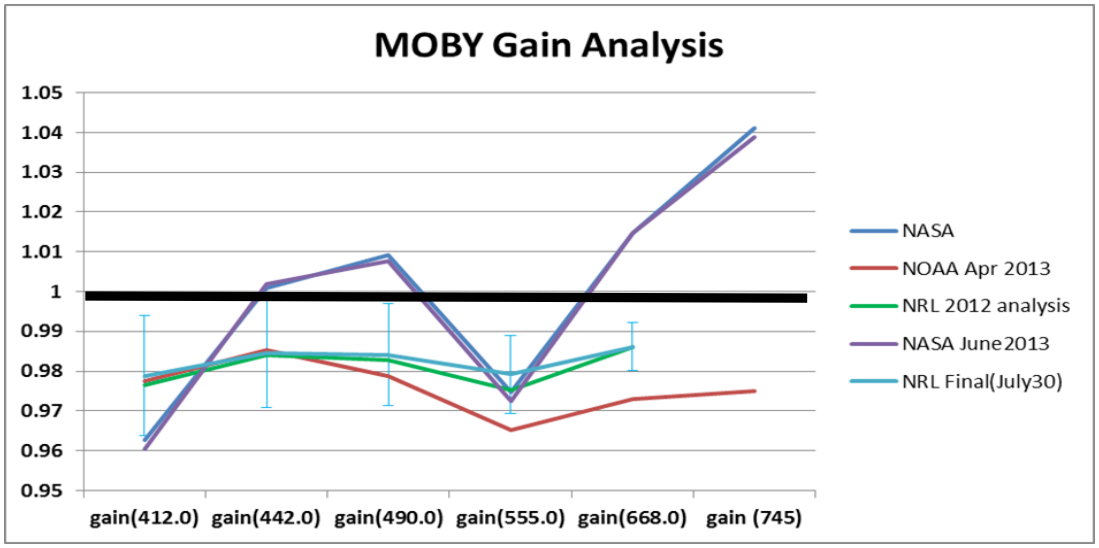
VIIRS Vicarious Calibration Evaluation

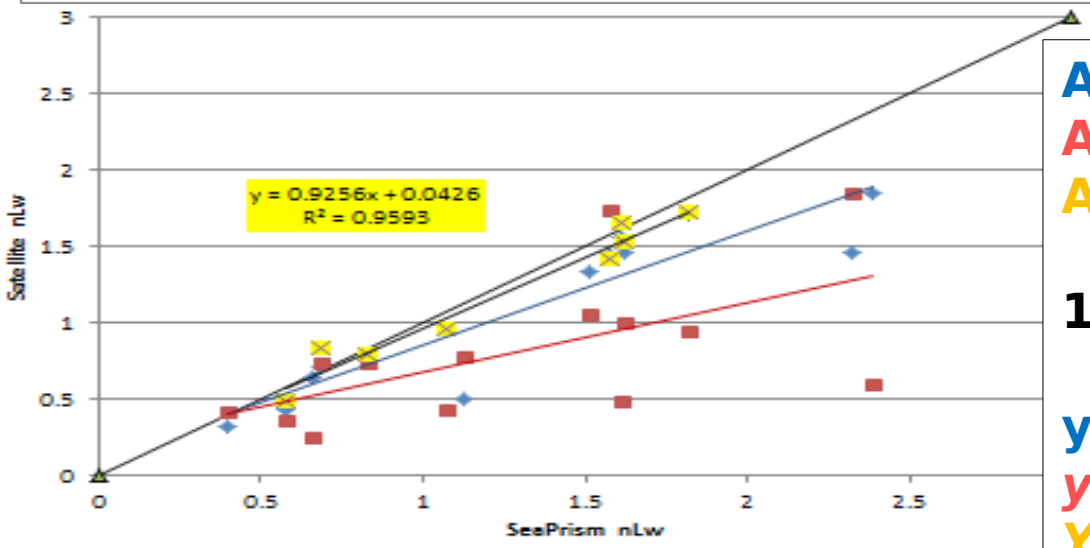


Vical

- Tuning sensor to match insitu

- Ratio of Satellite to in situ should optimally = 1

- Correction for errors due to AtmCorr and sensor calibration (drift/degradation)



Aeronet : APS

Aeronet : NOAA IDPS

Aeronet : APS w/Gains

1:1

y = 0.75x + 0.11 r²=0.84

y = 0.45x + 0.23 r²=0.35

Y = 0.93x + 0.04 r²=0.96

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MODIS and VIIRS Comparison to Aeronet-OC Sites

Pairing and Wavelength	slope	r2
AOC:MODIS 412	0.9455	0.8564
AOC:MODIS 442	1.0225	0.9306
AOC:MODIS 488	0.9465	0.9786
AOC:MODIS 532	0.9622	0.9823
AOC:MODIS 555	0.9360	0.9779

Pairing and Wavelength	slope	r2
AOC:VIIRS 412	0.9466	0.7895
AOC:VIIRS 442	1.0772	0.9322
AOC:VIIRS 488	1.0732	0.9775
AOC:VIIRS 555	1.0153	0.9865
AOC:VIIRS 667	0.9703	0.9571

- Data from JD 113 2013 to present
- Stringent set of criteria for inclusion

  (32 in situ data points)
- Both MODIS and VIIRS compare well to Aeronet-OC sites
- VIIRS slope values are slightly higher

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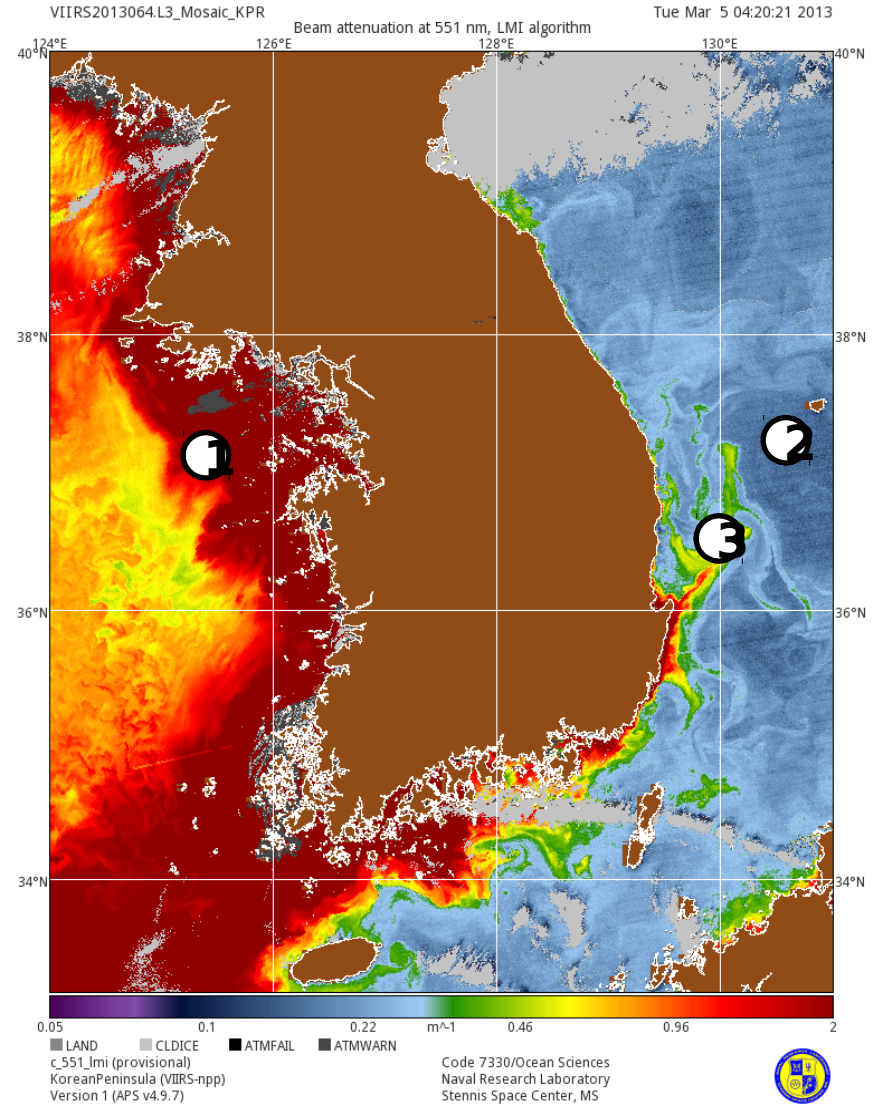
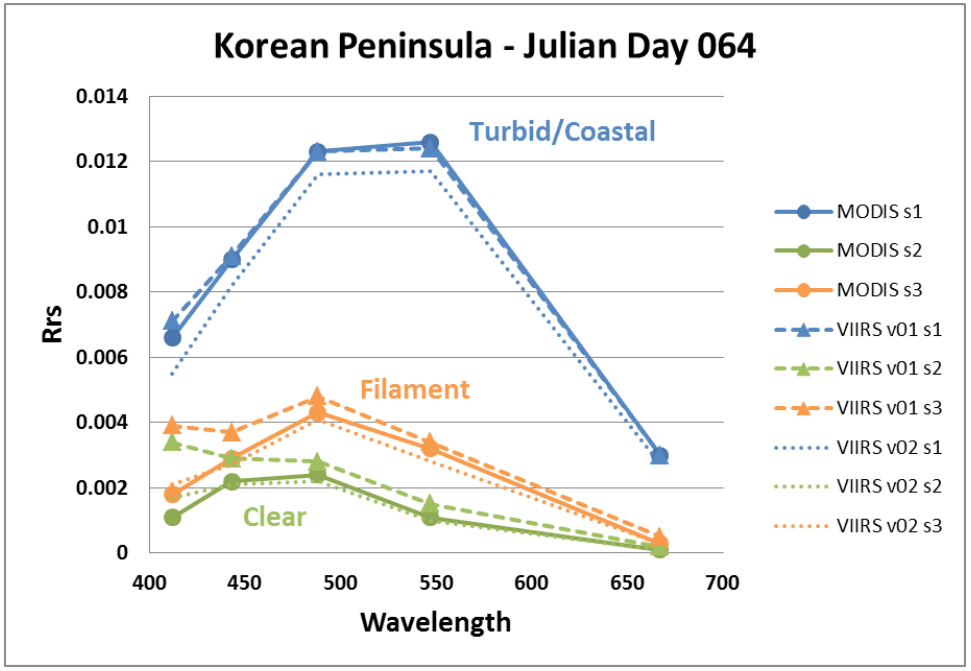
Korean Peninsula: MODIS – VIIRS Comparison



5 March 2013
VIIRS(gains) vs MODIS Rrs improvement at stations 2 & 3 in comparison to MODIS



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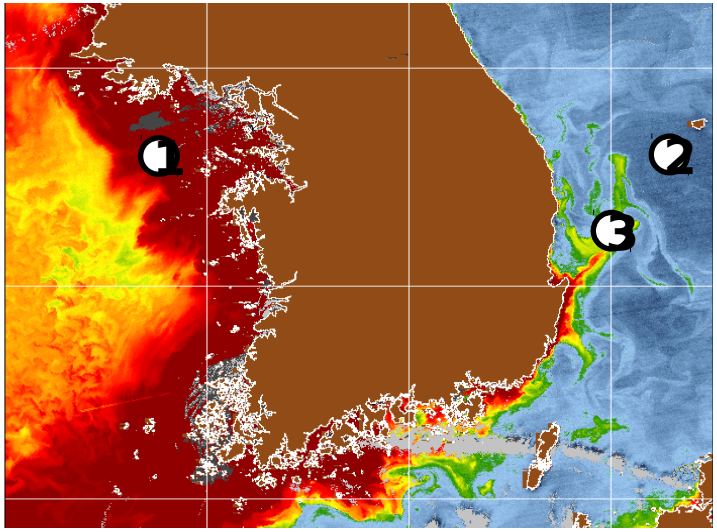
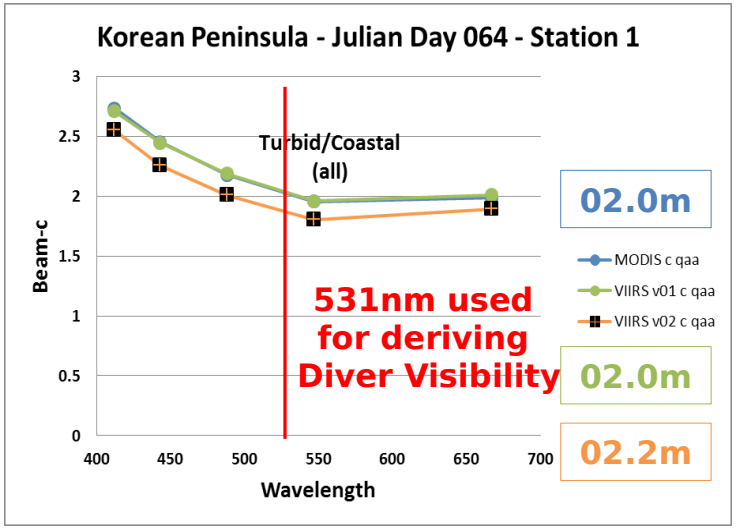
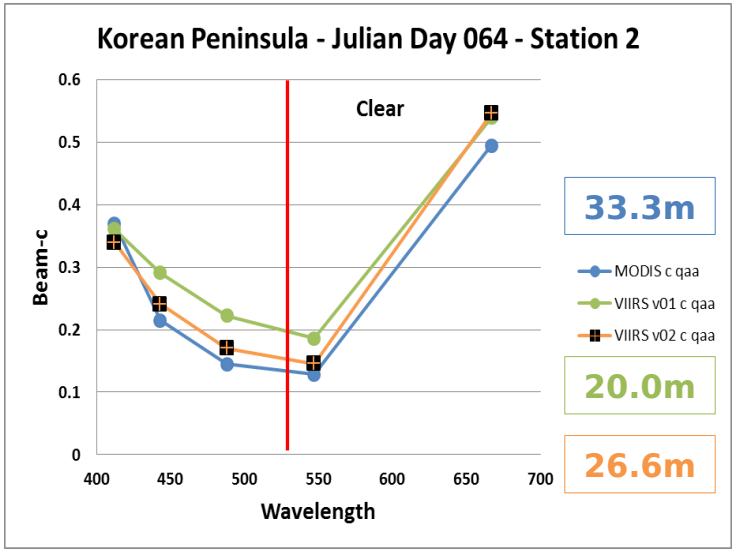
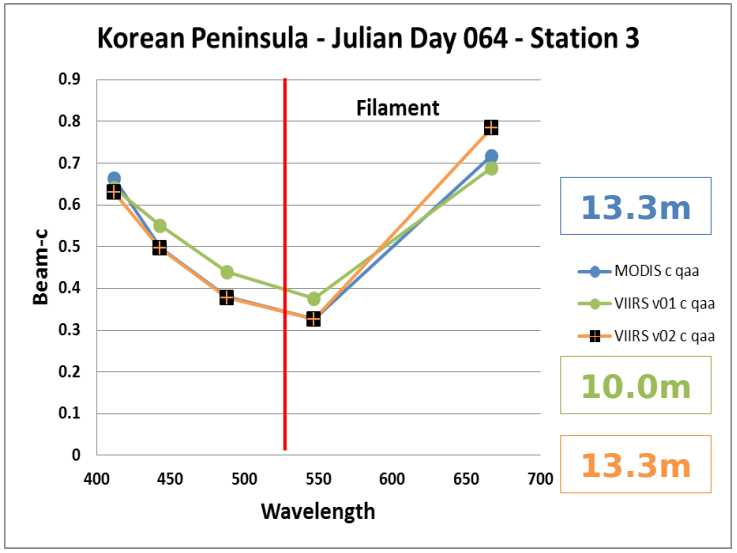
Diver Visibility Comparisons









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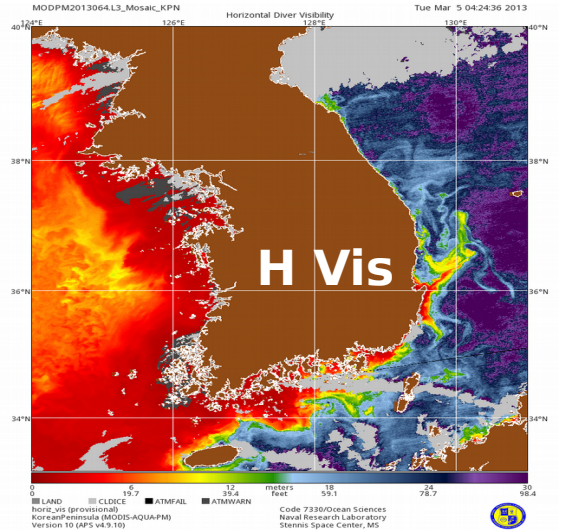
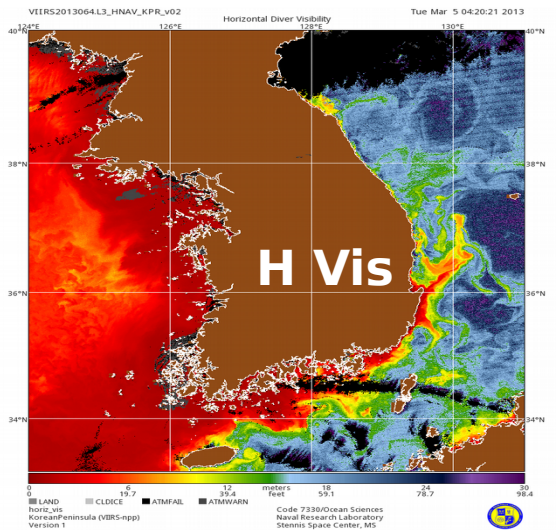
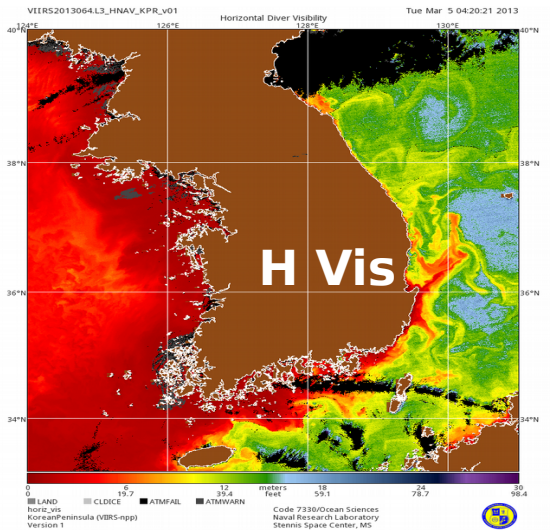
Horizontal and Vertical Visibility with Gains



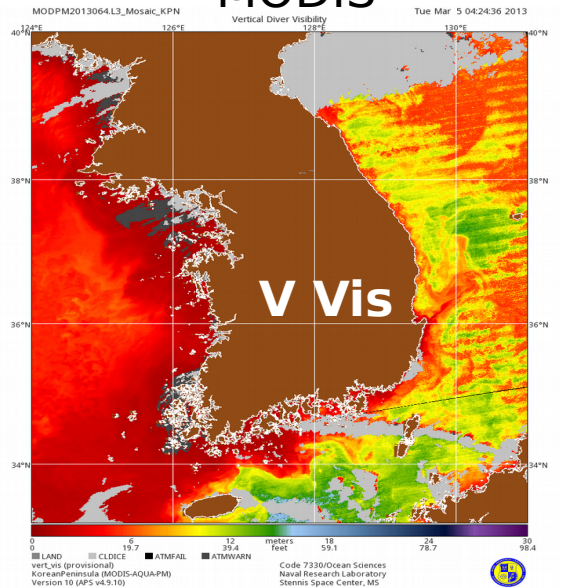
MODIS

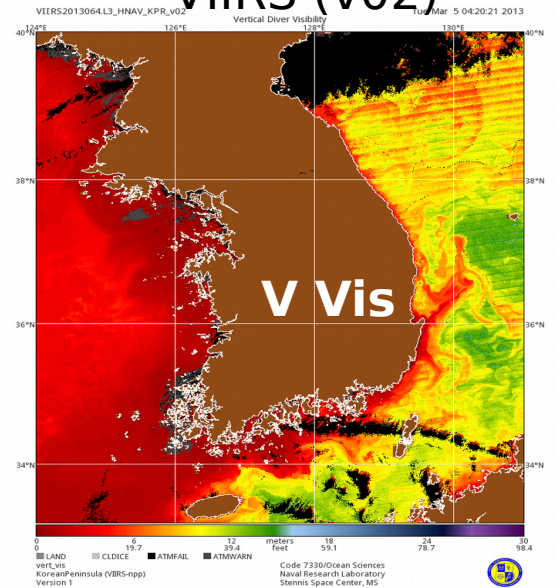


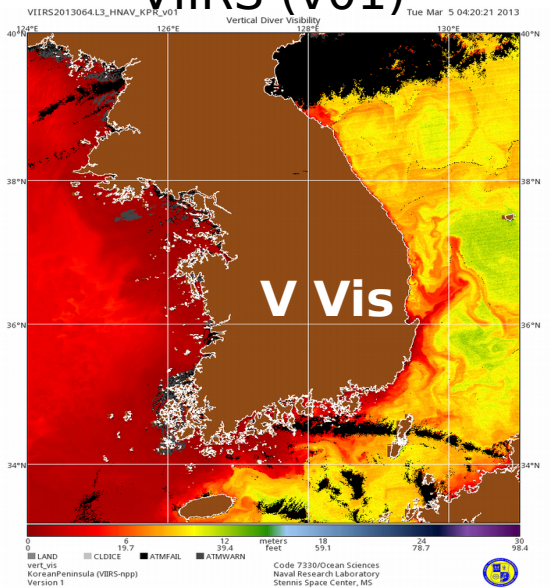
VIIRS (v02)



VIIRS (v01)







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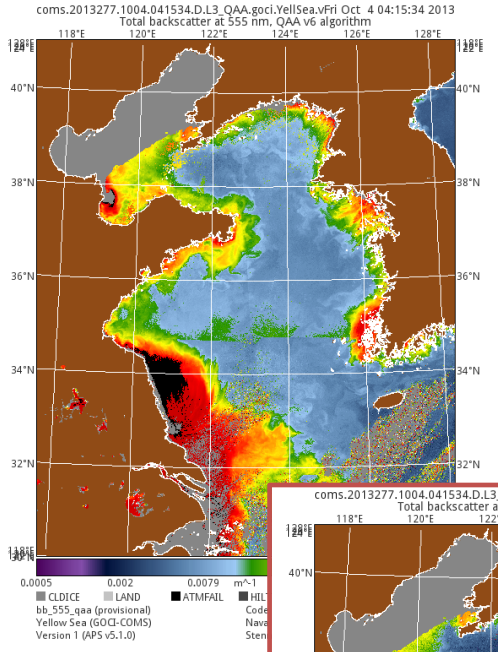
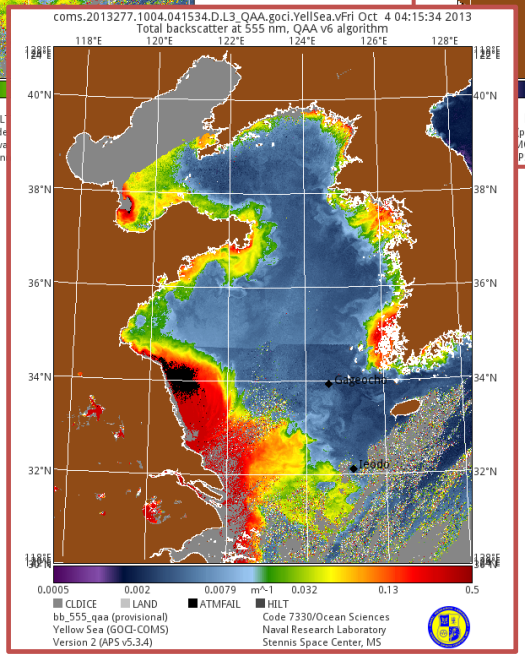
GOCI – MODIS – VIIRS Comparisons

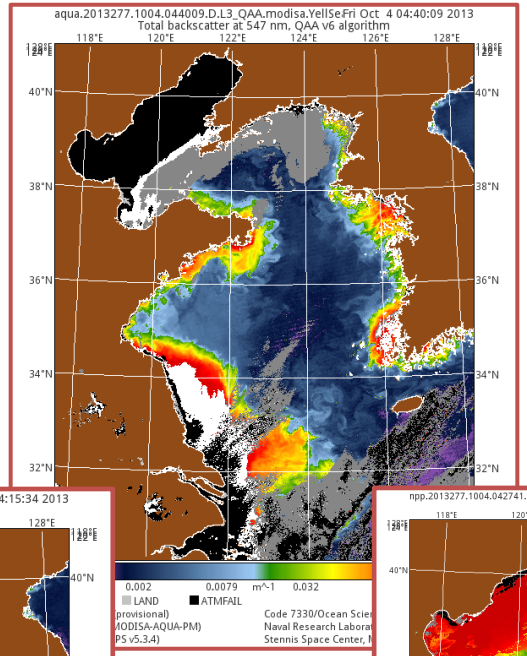
GOCI No Gains



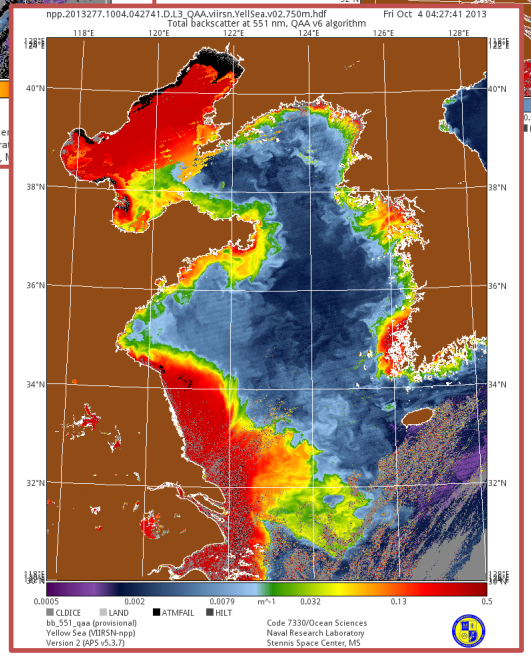
GOCI Gains



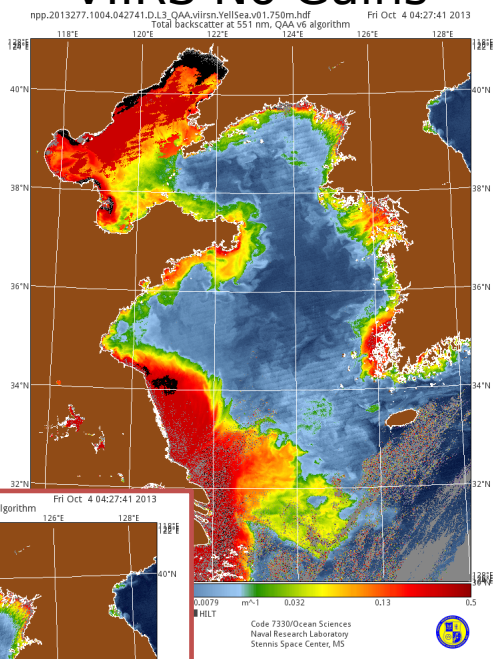
MODIS



VIIRS Gains



VIIRS No Gains



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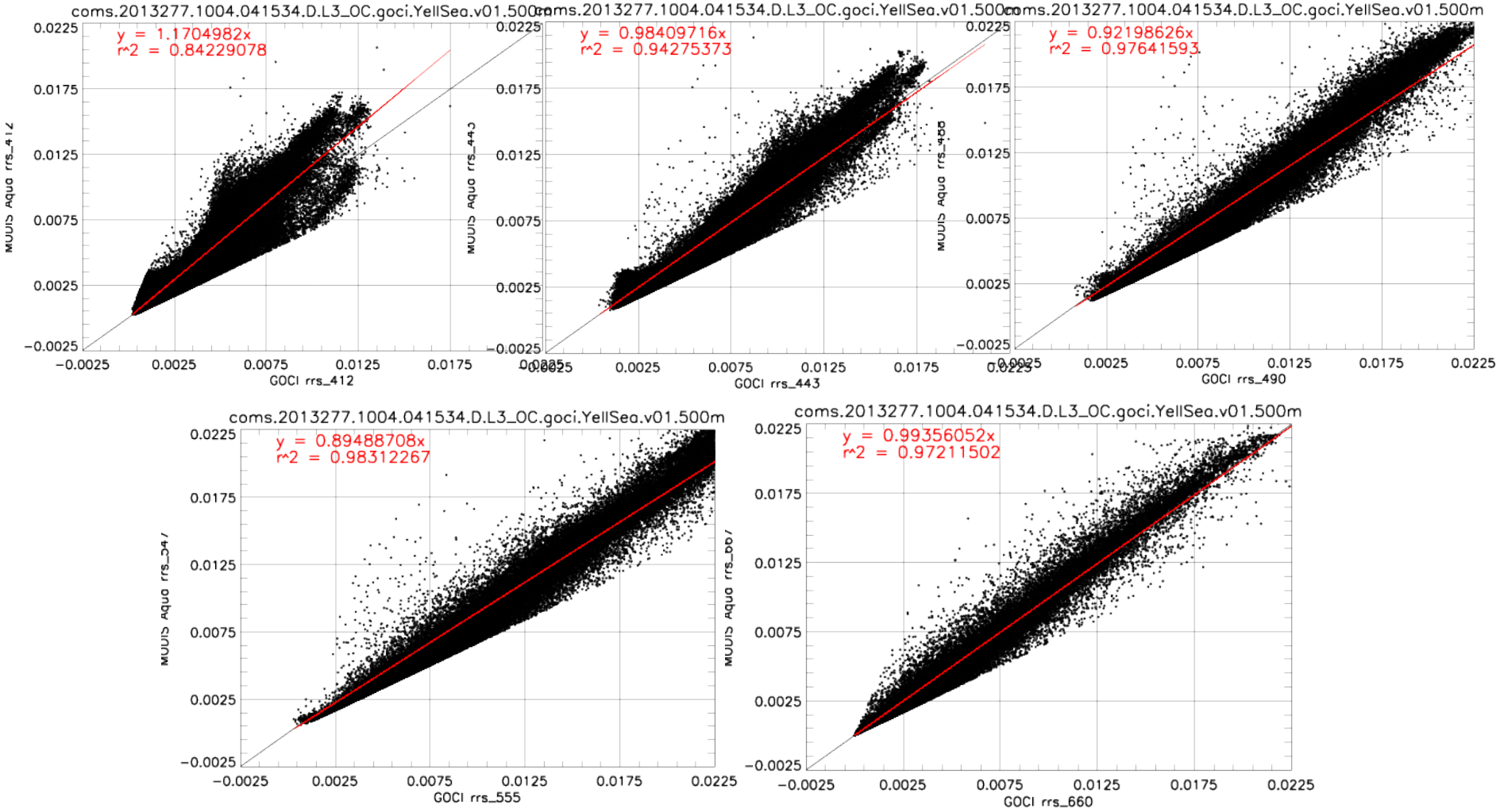
GOCI – MODIS Image Comparison (day 277)



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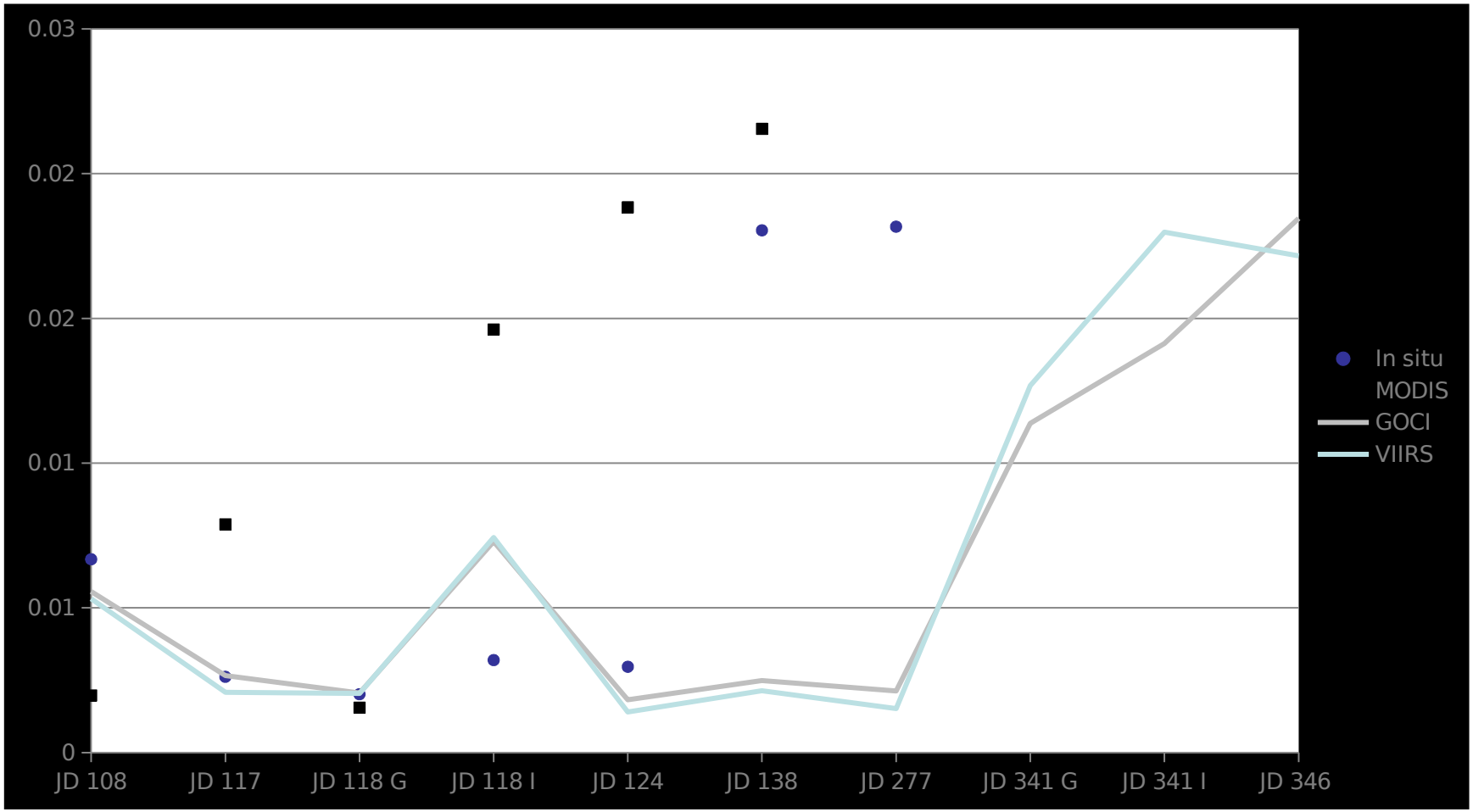
Sensor Comparison to in situ data in East China Sea



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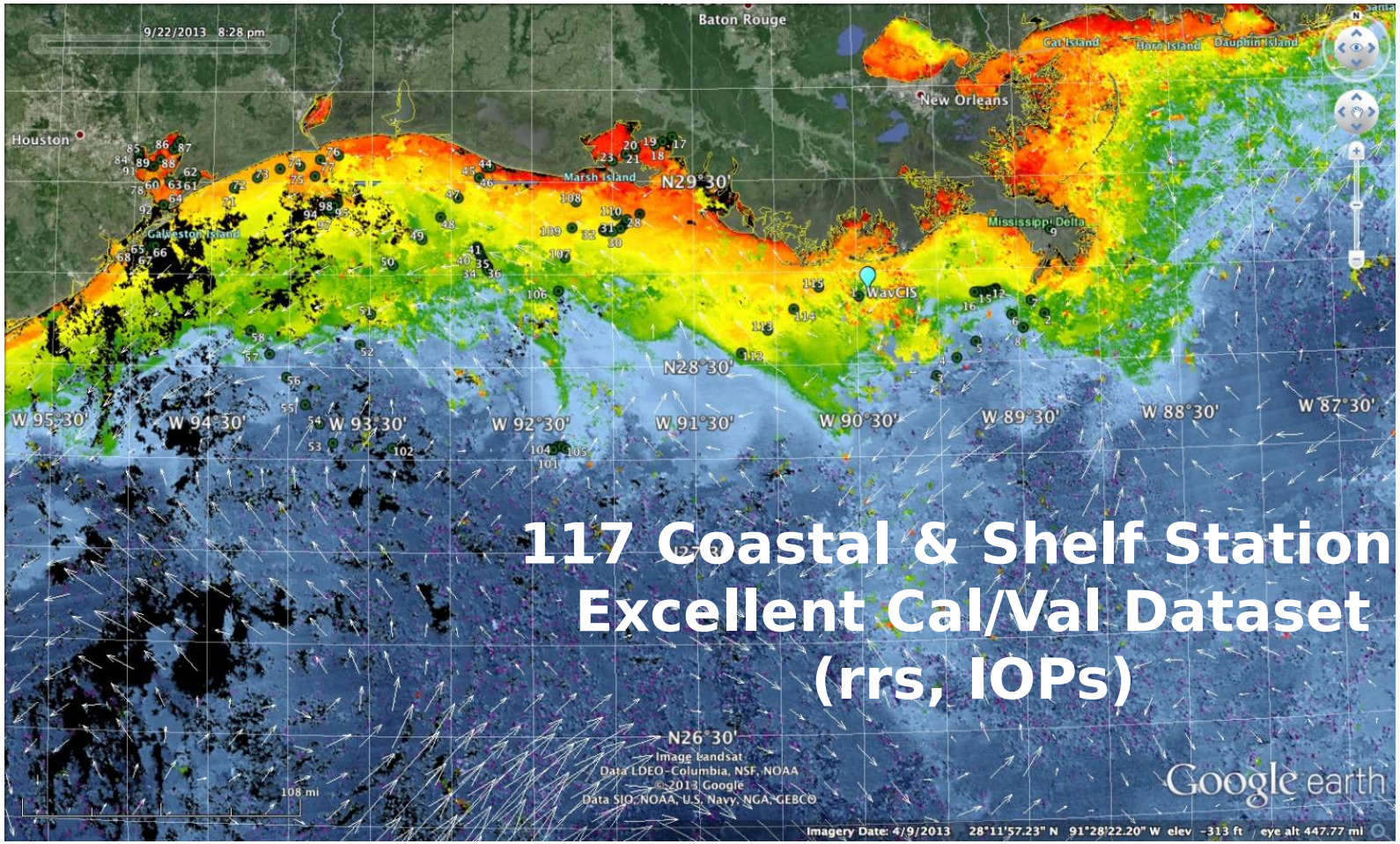
GEOCAPE Coastal Cruises for Cholorophyll 9-22 Sep 2013



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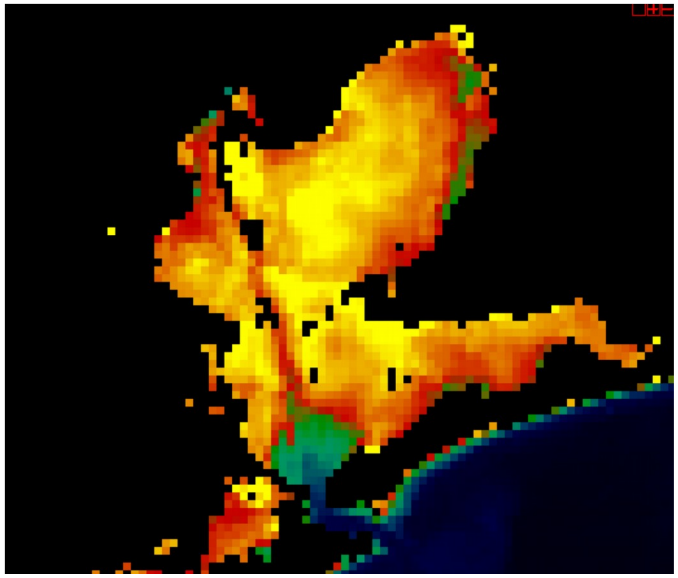
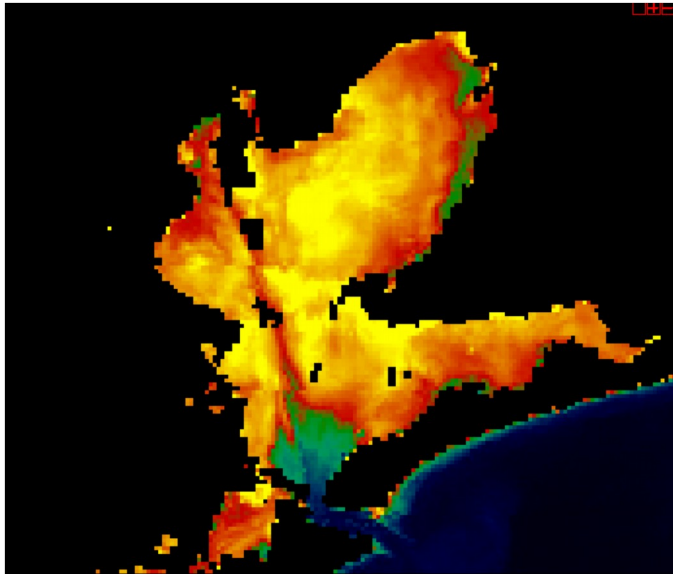
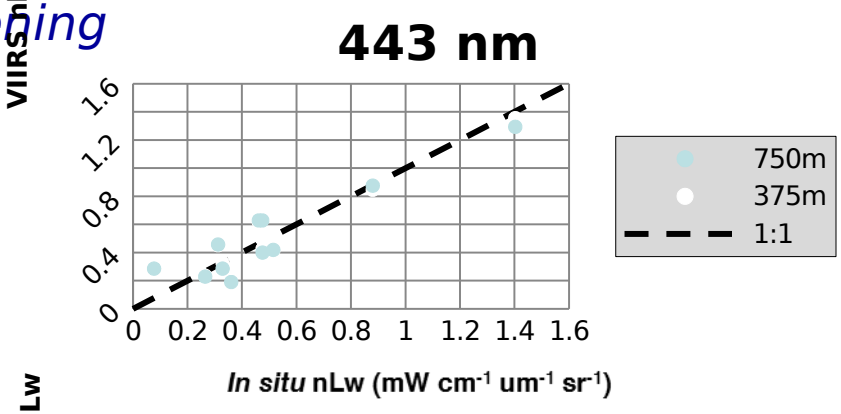
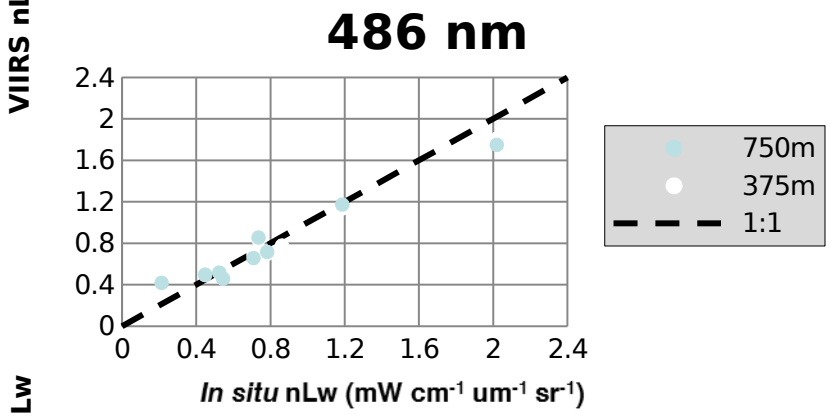
VIIRS Band Sharpening

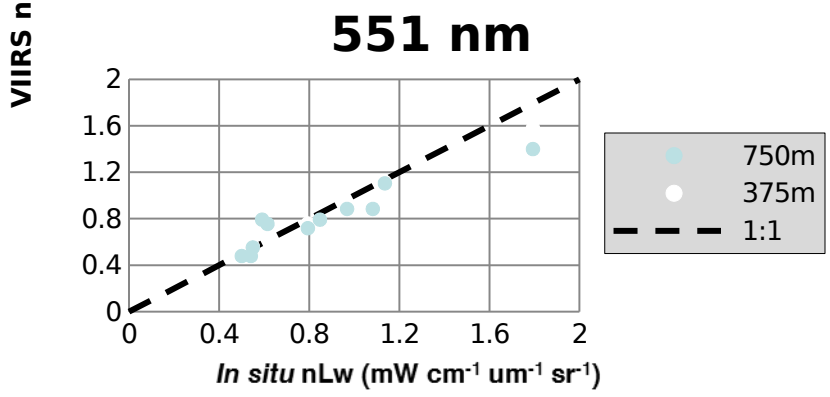




Currently Evaluating Spatial Improvement In Optical Properties Using High Resolution Optical Flowthru data (Nov2013 RV/Ocolor)







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Summary

- VIIRS & GOCI performing very well and ready for operational use to provide Navy Tactical Optical Products – Data Streams NAVO/NRL established – GOCI initial cal/val FY14
- AOPS V4.10 transition in March 2014 (Q2)

MODIS is aging!
VIIRS and GOCI are improving!
OLCI will be available soon!

  - Supports mission planning and operations for MIW, ASW, and SpecOps.
  - Provides quality inputs *to 3D optical models for forecasting the 3D optical environment and EO system performance*
- *AOPS software updates required for calibration changes in coastal waters; SDRs are evolving due to sensor radiometric calibration/degradation needing periodic updates which includes updates to gains (vicarious calibration) for improved, consistent and accurate Navy products*
- MODIS sensor still providing useful products but presently declining more rapidly. Will require attention and cal/val in the near-future for inter-sensor consistency with AOPS VIIRS and GOCI. NASA cal/val supports climate studies and occurs every 1-2 years. Based on what we and the ocean color community are seeing, more frequent

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Questions?

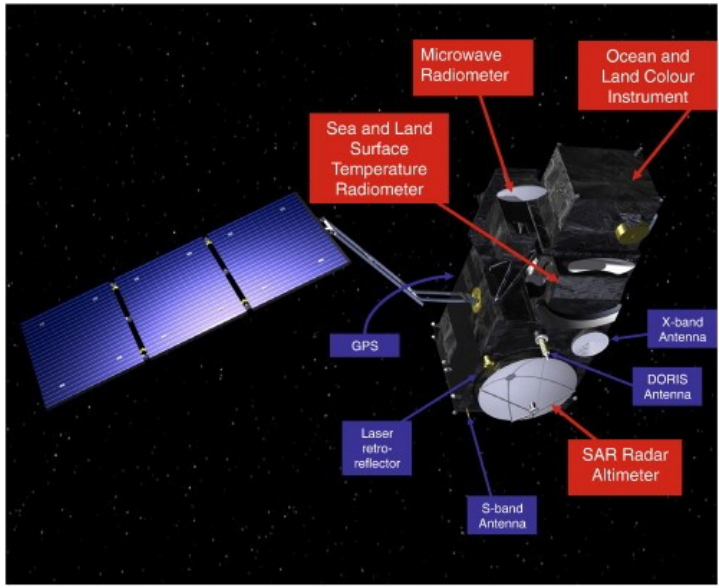
Backup Slides

OLCI on Sentinel 3A Status

Panned Launch Date: Q2/3FY15

Currently collaborating with European Space Agency On Navy Data Access – Working with NAVO – Bruce McKenzie, Paul Lyo

a. Complementary external support to Validation activities ***Provision of specific support on complementary Validation activities, including access to in situ infrastructure and data.***	
Name ***Name of organisation, institution, company, consortium***	**Naval Research Laboratory (NRL)**
Activity ***Objective, high level description of activity, etc.***	**Participate in vicarious calibration of OLCI data in coastal areas using AERONET-OC sites. Participate in calibration efforts for OLCI data using data collected in-situ during exercises.**
Benefit ***For R&D, user communities, at national / regional level, for EC / ESA, etc.***	**Accurate calibration of the Sentinel OLCI sensor is of interest to ESA, R&D, and User Community. Additionally, insure that calibration of Sentinel OLCI sensor is accurate in coastal regions, especially of interest to coastal communities and the US Navy.**
Planning ***Expected start of activity, schedule, availability of funding***	**Access to proxy OLCI data as soon as available to begin working on preparing the NRL and NAVO systems to receive and process the OLCI data once on-orbit. This effort is currently planned to begin during CY 2014**
Expectation / technical support from ESA ***Access to Sentinel core data***	**Access to proxy OLCI data prior to launch. Acces[illegible] launched and sensor has stabilized.**



Before Summer!

Planned FY15 Tasks

- Investigate/improve NIR atmospheric correction algorithm used in coastal waters for VIIRS and GOCI.
- Evaluate/improve/upgrade coastal ocean color properties through vicarious calibration, old/new IOP algorithms and coastal atmospheric correction (NIR iteration) using gains from green water sites.
- Operational Sentinel 3A OLCI with calibration and validation.
- Additional monitoring, calibration and validation for MODIS, VIIRS and GOCI required due to sensor degradation, drift, etc. (revisit every 3-6 months)
- Vicarious calibration and ocean color product validation important for continuous improvement of products being used operationally to forecast 3D optical properties in support of MIW mission planning and operations – TODS.
- Obtain/collect in situ IOP’s through collaborations or Navy exercises from gliders or ship for validation – 6-8 NRL coastal surveys.
- Upgrade/improve glint correction and masking.
- Investigate new salinity algorithm, derived for Gulf of Mexico by combining VIIRS and Aquarius, in other coastal regions – needed to assimilate into physical/circulation models for improved coastal/river outflow and buoyancy plumes.
- Software upgrades for GOCI, VIIRS, and MODIS (new calibration and LUT

Proposed Tasks (FY14)

- Continue SAVANT updates in “Golden Regions” for monitoring and calval for current operational sensors to insure stability and consistency thru calibration upgrades.
- Obtain and integrate GOCI 8 hourly scenes into operations to improve cloud removal, tracking of coastal optical properties, and operational support (NASA Data Stream Coming).
- Integrate frame correction for COMS GOCI to remove artifacts due to overlap and solar and sensor angles
- Complete initial COMS GOCI cal/val and perform necessary upgrades to account for sensor degradation and drift and insure accurate and consistent operational Navy ocean color products
- Establish data source for Sentinel-3 OLCI (ESA) w/proxy data for early/initial implementation (Underway with NOAA and NAVO).
- Continue cal/val upgrades due to sensor drift and degradation to insure consistent products.
- Develop optical properties for VIIRS at 375 m resolution using “band sharpening” techniques on 750 m resolution channels.
- Implement band shift for desired wavelength (ex. 531nm) for IOP’s using spectral models– LMI evaluation
- Develop, test, and integrate a new binning capability for reduced resolution grids for basin/global processing/mapping.
- Continue to monitor and include improved atmospheric correction methods
- Provide new ocean and operational products as they become available.
- IOP Coastal Cruises on NRL’s RV/Ocean Color – Need in situ data for algorithm

Preparing Tactical Ocean Optical Products for Future Polar-Orbiting Sensors: AOPS

Warfighter Requirements

• Provides a representation of the environment in accordance with Battlespace on Demand (BOND):

1)Tier 0 – Data (Inherent Optical Properties)
2)Tier 1 – Environment (sediment/chlorophyll, fronts, eddies)
3)Tier 2 – Performance (Diver visibility, Diver vulnerability, LIDAR performance)

• The ability to readily exploit new sensors provides surveillance in strategic areas

1) Potential to enhance utility of NTM queuing and performance surface products
2) Coastal optical forecasting
3) Provide inputs to tidal and coastal modeling
4) Enables development of advanced techniques for cloud removal and screening

• Given the lack of future planned satellites to support METOC, Navy tactical algorithms are required to be applied to ocean color sensors so all available sensing capabilities (including foreign) will support Navy operations.

• Ocean optical properties are required to support Special Forces operations. For example, the spatial and temporal variability of the water clarity severely restricts diver visibility which is required for Special Warfare, Expeditionary

Preparing Tactical Ocean Optical Products for Future Polar-Orbiting Sensors: AOPS

Warfighter Requirements (Cont.)

- From a broader perspective [**METOC Environment ICD, 2010**], ocean color satellites provide:

1) Characterization of ocean circulation and water mass characteristics
2) Capability to assimilate short wave radiation flux into circulation models. *Specifically, ocean absorption coefficients derived from ocean color sensors are used to determine subsurface heating resulting from short wave radiation*
3) Initialization fields required for forecast and prediction models. *(Ref. 1498 –LBSFI – TODS, 2013)*

- Real-time ocean optical properties are required for MIW to determine the performance field of laser imaging systems (ALMDS, AQS24)

1)This technique is extendable:

a. to provide a pre-deployment performance assessment for the CHARTS bathymetry system.
b. to determine areas where targets can and cannot be detected in the water and optimal sensor tow altitude off the bottom *based on sensor EO performance models.*

- This project also supports CNO validated requirements: **CINC OCEN 91-06** Ocean Prediction Models; **LITT OCEN 93-06** High